2 Biomedical Polymer Nanofibers for Emerging Technology

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Abstract  Nanofibers have been of great interest in the recent years, because of its huge potential to diverse fields, especially in biomedical applications. The most favorable feature is the dimension of nanofibers that resembles that of the natural collagen fibrils in nano scale. They thus provide extremely large surface area to volume ratio as compared to microfibers. Electrospinning is the most preferred method in producing nanofibers from polymers. In this chapter, an overview of polymer nanofibers is stated, specifically focusing on the electrospun nanofibers used in biomedical applications. Along with a brief description of history, principle, and operating parameters of electrospinning process, examples of specific functionalities are introduced through bulk and surface modifications of nanofibers. In addition, a broad range of biomedical application includes tissue-engineered scaffolds, wound dressings, medical device and implants, controlled drug release, and other applications in biosensor, biocatalyst, and bioenzyme. With the rapidly growing demand nanofibers should find its enormous potential for the future development of nanoscience and biomedicine.

Keywords  electrospinning, nanofiber, surface/bulk modification, medical polymer, nanobioscience

2.1 Introduction

Polymer nanofibers have attracted much attention in the last decade, because of their unique nano-sized features. Nanofiber is generally referred to as a fiber which has a diameter less than 100 nm. However, one also calls it nanofiber with

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diameters less than 1000 nm (submicron) produced by ultra-thin fiber manufacturing techniques (Grafe and Graham, 2003). The size of nanofiber is clearly contrasted with a human hair in scanning electron microscopy (SEM) images (Fig. 2.1). Methods for the production of polymeric nanofibers include drawing (Ondarcuchu and Joachim, 1998), template synthesis (Feng et al., 2002; Martin, 1996), phase separation (Ma and Zhang, 1999), self-assembly (Liu et al., 1999; Whitesides and Grzybowski), and electrospinning (Reneker and Chun, 1996). Electrospinning is the most popular and preferred technique, which is simple, cost-effective and able to produce continuous nanofibers from polymers to ceramics. It is an efficient fabrication process that can be utilized to assemble nanofibrous polymer mats (Dietzel et al., 2001; Huang et al., 2004). A variety of polymers have been successfully electrospun into nanofibers, mostly in polymer solution and some in polymer melt. While the conventional fiber spinning techniques, such as wet spinning, dry spinning, and melt spinning, produce polymer fibers with diameters in micrometer scale, electrospinning can generate polymer fibers in nanometer range. When the diameters of polymer fibers are reduced from micrometer to submicron or nanometer scale, some fundamental changes in physical and mechanical characteristics occur: extremely large surface area to volume ratio, flexibility in surface functionality, and improvement of mechanical property (e.g. stiffness and tensile strength), as compared to other traditional forms of materials. These advanced properties make polymer nanofibers an optimal candidate for many biomedical and industrial applications (Huang et al., 2003).

Figure 2.1  SEM images of the size of nanofiber and human hair

The use of polymer nanofibers for biomedical applications has some intrinsic benefits (Zhang et al., 2005). The most notable one is that they share a morphological proximity with natural extracellular matrix (ECM) components, for instance, collagen, which is composed of nanometer-scale (50 – 500 nm) multi-fibrils. The use of synthetic nanofibrillar matrix is thus expected to mimic